

Additive Manufacturing of Functional (Photoluminescent) Optical Components

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Additive Manufacturing could be a reliable process for mass production of optical components, due to its versatility in printing structures of varying complexities. In this paper, we would like to present our prototype results obtained from multiple material printing of quantum dot nanocomposites in two fashions: using different materials in subsequent layers, and using different material within a layer

1. Introduction

Additive Manufacturing (AM) has the potential to become a powerful tool in the realization of complex optical components. It is also possible to introduce optical properties like Photoluminescence (PL) into the raw material. This way, new sensor systems can be realized, which may be used to measure the absorption spectra of biological samples. This component can be individually adapted to the biological sample with respect to its optical responses.

2. Material Preparation

For functionalizing the printing material, quantum dots were introduced into the photopolymer resin used for printing. For the preparation of nanocomposites, the quantum dots obtained in powder form was suspended in toluene to form a colloid, which was then mixed with the photopolymer resin. Various solvents and methods were tried out for colloid formation [1], including the Schlenk technique (as shown in Fig.1), where care was taken to carry out the complete mixing process under nitrogen atmosphere.

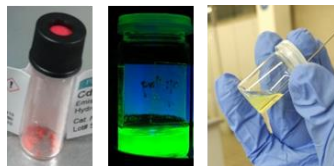


Fig. 1: QD obtained in powder form(left); QD Colloid in Toluene(centre); Resin mixed into the colloid(right)

Among the two resin matrices tested for multiple material printing, one was a customised resin matrix from the family of Organically Modified CERamics

(ORMOCER®), provided from ISC, Fraunhofer[2]. The quantum dots and resins used for forming the nanocomposites have been listed in Table 1.

Quantum Dots	Solvent	Resin
ZnCdSeS; λ_{em} -480nm	Toluene	Detax Luxaprint
ZnCdSeS; λ_{em} -580nm	Toluene	Detax Luaxprint
ZnCdSeS; λ_{em} -480nm	THF	ORMOCER®
ZnCdSeS; λ_{em} -530nm	THF	ORMOCER®
ZnCdSeS; λ_{em} -580nm	THF	ORMOCER®
ZnCdSeS; λ_{em} -630nm	THF	ORMOCER®

Table 1: Summary of Quantum Dots, Solvents and Photopolymers used in multi material printing

3. Printing the nanocomposites

a. Multiple Material Printing in printing axis (Z-Axis)

In the normal printing set up (shown in Figure 2, left and Figure 4 left), basic principle of printing using Autodesk Ember is depicted[1].

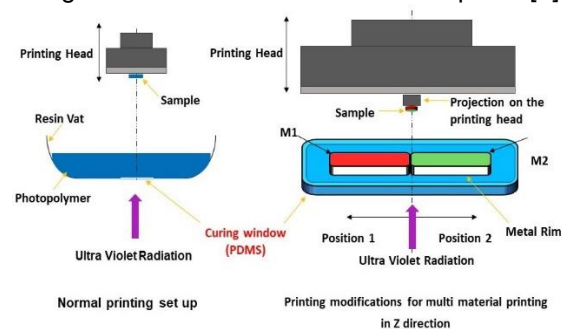


Fig.2: Normal printing set up(left); Printing set up adapted for MMP in Z Axis (right)

This glass piece is coated with PDMS, which traps in oxygen molecules from the atmosphere, leading to curing a single layer of resin into the printing head through oxygen inhibition [3]. With the QD nanocomposites, smaller amounts of test mixtures to print with, and including more than one material within the printing window is essential for smooth printing and efficient utilisation of mixtures.

For multi material printing (MMP) in Z axis (the axis of layer accumulation), the glass window, is divided into two compartments (see figure 2). These compartments are filled with two different resin mixtures. By controlling the printing process, a set number of layers is printed with one material, then changed to the next. An example is shown in figure 3.

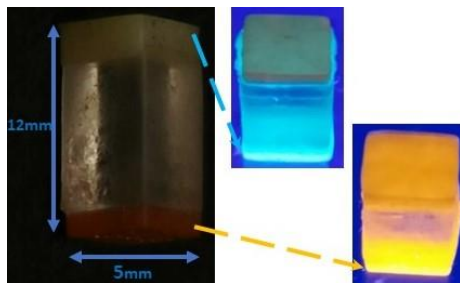


Fig.3: Multi material printed sample, with the first and last 1mm of the cuboid printed with QDs of 480nm and 580nm emission respectively (left); the sample subjected to UV (405nm)

b. Multiple Material Printing in the direction of the printing plane (XY plane)

In contrast to the previous set up where multiple materials are printed in different layers of the sample, the set up described here deals with printing multiple materials within a layer. In this case, the printing head projection itself is sectioned, so that they can individually move into each compartment simultaneously (see figure 4).

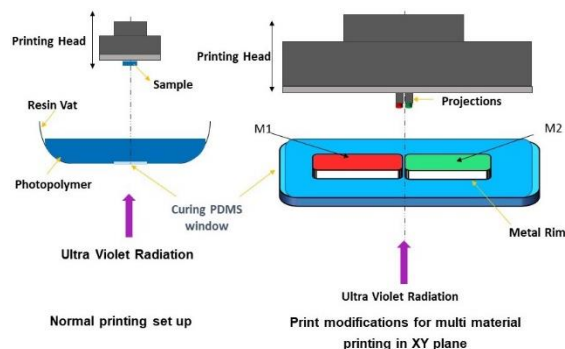


Fig.4: Normal printing setup (left); Printing set up adapted for MMP in XY Plane (right)

The multiple quantum dot mixtures are printed simultaneously, keeping the printing head's orientation static. In the MMP prototypes, the QD parts of the sample are cured at different spatial locations, and in the later part of the print, a common base printed on top of these rods, to form the final 'chip' like structure, as shown in figure 5. This set up is currently capable of printing 5 mixtures, all the same base resin matrix and different QDs.

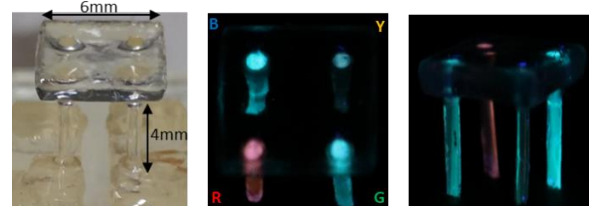
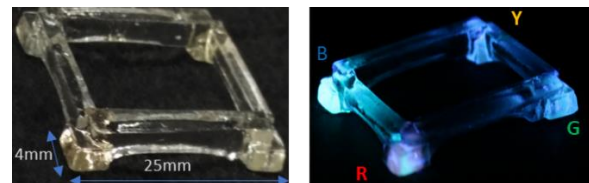


Fig.5: MMP Samples, in two different designs (above and below), printed with AM adapters



4. Summary

Trial runs for realizing multiple material printing with Quantum Dots embedded nanocomposites through SLA has been successfully completed. At the moment, focus is on optimising the design of such a multiple QD chip that can be reliably reproduced. Optical characterisation needs to be done regarding the collective emission spectra from this chip, followed by field tests as a part of a spectroscopic set up for spectral analysis of samples.

5. Reference

[1] S. Suresh Nair, J. Nuding, A. Heinrich, "3D-printed optical active components ", Proc. SPIE 10529, Organic Photonic Materials and Devices XX, 105290W (21 February 2018); doi: 10.1117/12.2287427

[2] M. Klein, S. Steenhusen, ISC Fraunhofer, Germany

[3] <http://www.instructables.com/id/SLADLP-Basics/>